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(71) Applicant: VICTOR COMPANY OF JAPAN, LTD.
12, Moriya-Cho 3-Chome, Kanagawa-Ku
Yokohama-Shi, Kanagawa-Ken (JP)

(72) Inventor: Takanashi, Itsuo
3-7-12 Oomachi, Kamakura-shi
Kanagawa-ken (JP)
Inventor: Nakagaki, Shintaro
6-2 Koyo-cho
Miura-shi, Kanagawa-ken (JP)
Inventor: Negishi, Ichiro
301, Copo Kotobuki, 5-8-10, Ooyabe
Yokosuka-shi, Kanagawa-ken (JP)
Inventor: Suzuki, Tetsuji
202, Morisaki Park Sanei, 2-3-13, Morisaki
Yokosuka-shi, Kanagawa-ken (JP)
Inventor: Tatsumi, Fujiko
2-12-3, Chuo, Nishi-ku
Yokosuka-shi, Kanagawa-ken (JP)
Inventor: Takahashi, Ryusaku
302, Château obi, 1719-1, Nobi
Yokosuka-shi, Kanagawa-ken (JP)
Inventor: Maeno, Keiichi
102, Morisaki Park Sanei, 2-3-13, Morisaki
Yokosuka-shi, Kanagawa-ken (JP)

(74) Representative: Crawford, Andrew Birkby et al
A.A. THORNTON & CO. Northumberland House 303-306 High Holborn
London WC1V 7LE (GB)

(54) Polarization converter for converting randomly polarized light to linearly polarized light.

(57) An efficiency polarization converter of few optical components for converting a randomly polarized light into a single beam of linearly polarized light, comprises a first optical device receiving the random light and projecting two linearly polarized lights one projected in a first direction, another to a second optical device which changes the polarization plane thereof, the polarization changed light being directed by a third optical device to the first direction, thereby the two linearly polarized light are combined and aligned to have a common polarization to become the single beam linearly polarized light projected in the first direction. Typical first optical device is a polarization beam splitter (PBS_1, PBS_4), a typical second optical device is a quarterwave plate with a mirror (M), a halfwave plate (6) or a Fresnel rhomb prism (9) with a mirror (M), or a photomodulation material (PML) interposed between biased electrodes (Et, Er) with a mirror (M), a typical third optical device is a polarization beam splitter (PB_2), a prism (7) or a mirror (M). The first and third optical devices may be combined to a 3-prism structure (PB_3). The polarization converter may be used with liquid crystal light modulators (11, 13) to utilize image display systems.

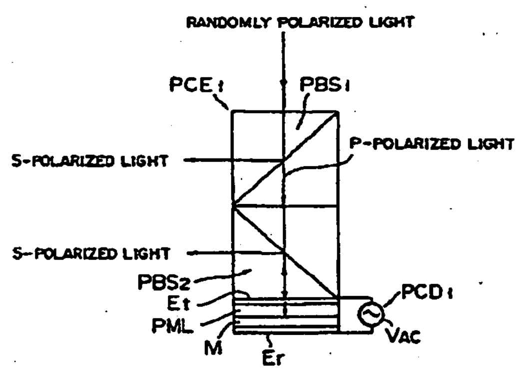

FIG. 1

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POLARIZATION CONVERTER FOR CONVERTING RANDOMLY POLARIZED LIGHT TO LINEARLY POLARIZED LIGHT

BACKGROUND OF THE INVENTION

The present invention relates to a polarization converter which converts a randomly polarized light into a linearly polarized light highly efficiently.

Recently, large screen image projectors utilizing a light modulators of twisted nematic type liquid crystal are becoming popular. For this type of image projector, a linearly polarized light is needed as a projection light, the same is true for other type of image projectors utilizing an optical device having an electro-optic effect for the operation of the projectors.

In this regard, a conventional system to obtain such a linearly polarized light is that a randomly polarized light generated from a high intensity light source such as an incandescent or arc lamp, is allowed to be passed through an optical analyzer. However, this conventional system is poor in efficiency as an energy of the utilizable linearly polarized light is less than a half of the energy of the original randomly polarized light.

Some improvements on this poor efficiency problem are disclosed in the following prior arts :

(1) Polarization Converter Element for High Intensity Liquid Crystal Projection System, preprint No. 5-page 34 for the 1989 Fall Convention of The Institute of Electronics, Information and Communication Engineers, in which a P-polarized light is converted into an S-polarized light or vice versa by a total reflection system.

(Note : P-polarized light is a linearly polarized light of which the plane of polarization is perpendicular to the plane of incidence of the light before the conversion, whereas the S-polarized light is a linearly polarized light of which the plane of polarization is perpendicular to the P-polarized light.)

(2) Japanese Laid-open Patent Application No. 1 (1980)-201693 in which a P-polarized light and an S-polarized light are combined together after being modulated by respective liquid crystal modulators.

However, the system of the prior art (1) involves many optical components making the system too complicated and the P-polarized light and the S-polarized light produced in the system have their respective light paths different each other which is liable to cause a disagreement between the two lights upon landing on the light modulator (liquid crystal panel) for image projection. The system of the prior art (2) requires two independent light modulators (liquid crystal panels) to produce modulated light beams to be combined thereafter by a polarization beam splitter, because of this optical arrangement, the system is liable to cause a disagreement between two images respectively produced by the two independent light modulators.

SUMMARY OF THE INVENTION

A primary object of the present invention is to provide an improved polarization converter which converts a randomly polarized light into a linearly polarized light highly efficiently using a minimum number of optical components.

According to one concept of the present invention, a first optical device receives a randomly polarized light from a light source and produces first and second linearly polarized lights having their polarization planes a predetermined angular relationship between them but advancing in a first and second directions respectively. Second optical device changes the polarization plane of the second linearly polarized light into the same polarization plane as the polarization plane of the first linearly polarized light. Third optical device direct the polarization changed second linearly polarized light to the first direction so that a beam of linearly polarized light which is a combined product of the first and second linearly polarized lights projected in the first direction, is obtained.

In more specific aspects of the invention, the first optical device may be a polarization beam splitter comprising a pair of rectangular prisms combined together to form a 45 degree boundary plane between them which functions as a polarizer to produce the first and second linearly polarized lights, the second optical device may be a polarization converting device comprising a pair of electrodes, one of which is transparent, interposing a photomodulation layer and a mirror layer, a bias source providing an electric potential to the pair of electrodes, or a combination of a quarterwave plate and a mirror laminated thereto, or a combination of a Fresnel rhomb prism and a mirror provided thereto, or simply one halfwave plate, the third optical device may be a polarization beam splitter having the same structure as the one mentioned earlier, or one rectangular prism or simply one mirror aligned parallel with the 45 degree boundary plane. Further, the first and third optical devices may be combined to one optical block comprising a top, center and bottom rectangular prisms stacked each other so as to form two polarizing boundary planes between the prisms having a 90 degree angular relationship between the two boundary planes.

A primary advantage of this invention is to provide a high efficiency polarization converter of few constituting optical components, which converts randomly polarized light into a beam of linearly polarized light without wasting virtually the energy of the original

randomly polarized light incident to the polarization converter. The invention and its advantages will become more apparent from the detailed description of the invention presented below.

BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a diagrammatic representation of a polarization converter according to a first embodiment of the present invention.

Fig. 2 is a diagrammatic representation of a polarization converter according to a second embodiment of the present invention, which is a modified version of the first embodiment shown in Fig. 1.

Fig. 3 is a diagrammatic representation of a polarization converter according to a third embodiment of the present invention, which is a modified version of the first embodiment.

Fig. 4 is a diagrammatic representation of a polarization converter according to a fourth embodiment of the present invention.

Fig. 5 is a diagrammatic representation of a polarization converter according to a fifth embodiment of the present invention, which is a modified version of the fourth embodiment.

Fig. 6 is a diagrammatic representation of a polarization converter according to a sixth embodiment of the present invention, which operates differently from the fifth embodiment.

Fig. 7 is a diagrammatic representation of a polarization converter according to a seventh embodiment of the present invention in which the same polarization converter shown in Fig. 6 is used but is operated differently.

Fig. 8 is a diagrammatic representation of a polarization converter according to an eighth embodiment of the present invention, which is a modified version of the third embodiment.

Figs. 9 to 12 are diagrammatic representations of display system using a polarization converter of the present invention.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Polarization converters according to the present invention will be described hereinbelow in detail with reference to the attached drawings.

In Fig. 1 a polarization converter PCE_1 comprises a first polarization beam splitter (first splitter) PBS_1 to a top plane of which a randomly polarized light from a light source (not shown) is incident, contacted to a bottom plane of the first polarization beam splitter is a second polarization beam splitter (second splitter) PBS_2. A polarization converting device PCD_1 comprising from a top thereof a transparent electrode Et, a photomodulation layer member PML, a reflecting mirror layer (possibly dielectric mirror) M and an electrode Er, is further attached to a bottom plane of the second splitter. A bias potential is applied from an electric source Vac between the transparent electrode Et and the electrode Er to generate an electric field within the photomodulation layer member PML and the reflecting mirror layer M. A material of the photomodulation layer member PML may be lithium niobate ($LiNbO_3$), PLZT, twisted nematic liquid crystal or other materials having an electro-optic effect or birefringence. The bias potential from the electric source Vac, the material and a thickness of the photomodulation layer member PML are so determined that the polarization converting device PCD_1 functions to convert a P(S)-polarized light incident thereto into an S(P)-polarized light.

The first and second splitters PBS_1 and PBS_2 are typically cubical optical blocks each being a pair of prisms combined together to form a 45° boundary plane where multiple layers of film are sandwiched to serve as a polarizer, further, the two optical blocks are so stacked each other that the two boundary planes of the respective splitters PBS_1 and PBS_2 form a right angle as shown in Fig. 1.

An operation of the first embodiment of the present invention is as follows :

The randomly polarized light (random light) enters to the first splitter PBS_1, through the top plane thereof, an S-polarized light component of the entered random light is reflected at the boundary plane to exit from a left (in Fig. 1) plane of the first splitter PBS_1, whereas a P-polarized light component of the entered random light is allowed to pass the first splitter PBS_1 and advances into the second splitter PBS_2 then to a polarization converting device PCD_1 through the transparent electrode Et thereof. The P-polarized light (component) is converted into an S-polarized light as explained previously when the entered light travels through the transparent electrode Et the photomodulation layer member PML reflecting mirror layer M where the light is reflected back to the photomodulation layer member PML and to the transparent electrode Et.

Accordingly the light converted into the S-polarized light reenters the second splitter PBS_2 through the bottom plane thereof and is reflected by the boundary plane thereof to exit from the left (in Fig. 1) plane thereof, As a result, the S-polarized light projected from the second splitter PBS_2 advances parallel with the S-polarized light projected from the first splitter PBS_1, forming together a single beam of linearly polarized light (S-polarized light) advancing toward left in Fig. 1.

It should be noted that the electrode Er can be made to an electroconductive mirror so that the reflecting mirror layer M is omitted from the polarization converting device PCD_1. The same can be applied to the electrode Er shown in Fig. 2.

Referring now to Fig. 2, in the second embodi-

ment of the present invention, a feature of a polarization beam splitter PBS_3 is a stacked structure of three rectangular prisms as such that a bottom half (prism) of the cubic shape first splitter PBS_1 and a top half (prism) of the cubic shape second splitter PBS_2 in Fig. 1 are combined to form a single piece of center prism 1, this leaves a top prism 2 and a bottom prism 3 of the respective first and second splitter PBS_1 and PBS_2 in Fig. 1, further, the both boundary planes thereof remain and function in the same manner as they do in Fig. 1. The polarization converting device PCD_1 remains unchanged. Since the polarization converter PCE_2 of the second embodiment operates exactly in the same manner as the first embodiment does, a detailed operation of the second embodiment is omitted.

In Fig. 3 which shows a third embodiment of the present invention, a polarization converter PCE_3 includes the same components shown in Fig. 1 except the polarization converting device PCD_1 which is replaced with a polarization converting device PCD_2 in the third embodiment. The polarization converting device PCD_2 has a laminated structure of a $\lambda/4$ wave plate 5 and a reflecting mirror layer M and is contacted to the bottom plane of the second splitter PBS_2. The P-polarized light incident to the polarization converting device PCD_2 from the second splitter PBS_2 is converted to a S-polarized light as it travels within the polarization converting device PCD_2, the light converted to the S-polarized light reenters the second splitter PBS_2, the rest of the operation is identical to the operation of the first embodiment. Naturally, bottom and top prism sections of respective first and second splitters PBS_1, and PBS_2 can be made to a single piece of center prism 1 as sbown in Fig. 2.

Fig. 4 shows a polarization converter PCE_4 which is a fourth embodiment of the present invention, in which a halfwave plate 6 is sandwiched between a polarization beam splitter (splitter) PBS_4 and a prism 7. A structure of the splitter PBS_4 is similar to the first splitter PBS_1 and a boundary plane of which is aligned parallel to a reflective plane 7a of the prism 7. The splitter PBS_4 functions similar to the first splitter PBS_1 does in Fig. 1 regarding a randomly polarized light incident to a top plane thereof, i.e. the splitter PBS_4 projects an S-polarized light to the left in Fig. 4 and passing a P-polarized light toward the halfwave plate 6 where the P-polarized light is converted into an S-polarized light which is in turn directed to the left by the reflective plane 7a to form a single beam of linearly polarized (S-polarized) light together with the S-polarized light from the splitter PBS_4.

Fig. 5 is a fifth embodiment of the present invention, which is a modified version of the one shown in Fig. 4, i.e. the prism 7 is replaced with a reflective mirror 8 now in Fig. 5, which is aligned parallel with the boundary plane of the splitter PBS_4. This polarization converter PCE_5 operates in the same manner as the polarization converter PCE_4 shown in Fig. 4 does.

The polarization converter PCE_5 can be operated differently as shown in Fig. 6 as PCE_6 which is a sixth embodiment of the present invention. In this configuration, the incident randomly polarized light is projected parallel to an extending direction of the halfwave plate 6 of the splitter PBS_4, a P-polarized light component of the incident light continues to advance along a path of the incident light and is projected out of the splitter PBS_4, on the other hand, an S-polarized light component reflected at the boundary plane of the splitter PBS_4 advances perpendicular to the halfwave plate 6 where it is converted to a P-polarized light, which is in turn directed by the reflective mirror 8 to project parallel with the P-polarized light component explained before. As a result, a single beam linearly polarized light projected along the path of the incident randomly polarized light, is obtained.

Note that the single beam of linearly polarized light consequently obtained in the embodiments 1 through 5, projects perpendicular to a direction of the incident randomly polarized light, whereas it is parallel in the sixth embodiment, this increases a flexibility of image projector designs.

Fig. 7 shows a seventh embodiment of the present invention, in which the same polarization beam splitter PBS_3 shown in Fig. 2, is used, the polarization converting device PCD_1 is attached to a lower right plane of the center prism 1. In the polarization converting device PCD_1, the electrode Er is the type of electroconductive mirror as explained previously.

In this embodiment, a randomly polarized light (random light) is introduced to the upper half of the center prism 1 to hit an upper boundary plane PBS_{3a} through an upper right plane of the center prism 1, a P-polarized light component (P-polarized light) of the random light continues to advance along a path thereof and is projected out of the splitter PBS_3 passing through the upper boundary plane PBS_{3a} and the prism 2, whereas an S-polarized light component (S-polarized light) of the random light is reflected and directed by the upper boundary plane PBS_{3a} toward a lower boundary plane PBS_{3b} which is at right angles to the upper boundary plane PBS_{3a} in turn, the S-polarized light is reflected by the lower boundary plane PBS_{3b} toward the polarization converting device PCD_1 and is reflected back to the splitter PBS_3 by the electrode Er of electroconductive mirror, when the S-polarized light travels within the polarization converting device PCD_1, it is converted to a P-polarized light and is projected out of the splitter PBS_3 passing through the lower boundary plane PBS_{3b} and the bottom prism 3. As shown in Fig. 7 the splitter PBS_3 and the polarization converting device PCD_1 are so arranged that the P-polarized light thus converted and projected, advances parallel with the P-polarized light projected through the top prism 2 to form a single beam of linearly polarized (P-polarized) light

altogether.

Note that the splitter PBS_3 can be replaced with a pair of the first and second splitters PBS_1 and PBS_2 shown in Fig. 1 or Fig. 3.

Fig. 8 shows a polarization converter PCE_8 which is an eighth embodiment of the present invention, in Fig. 8 the first and second splitters PBS_1 and PBS_2 in the first embodiment as per Fig. 1 are employed, the first splitter PBS_1 receives a randomly polarized light and projects an S-polarized light to the left like in the first embodiment. A Fresnel rhomb prism 9 is attached to a bottom of the second splitter PBS_2, a reflecting mirror layer M same as the one in the polarization converting device PCD_1, is provided to a bottom of the Fresnel rhomb prism 9. The Fresnel rhomb prism 9 together with the mirror M serves as a polarization converting device which functionwise replaces the polarization converting device PCD_1 of the polarization converter PCE_1 in Fig. 1. When the P-polarized light projected from the second splitter PBS_2 and is projected normal to a top plane of the Fresnel rhomb prism 9 and travels within the Fresnel rhomb prism 9 being reflected by the mirror Mm the P-polarized light is converted into an S-polarized light and is projected back into the second splitter PBS_2 retracing a light path along which the P-polarized light advances through the second splitter PBS_2 and enters the Fresnel rhomb prism 9. As a result, the S-polarized light reentered the second splitter PBS_2 is directed to the left by the boundary plane thereof and advances parallel with the S-polarized light projected from the first splitter PBS_1 to form a single beam of linearly polarized (S-polarized) light together.

Note that the pair of first and second splitters PBS_1 and PBS_2 can be replaced with the polarization beam splitter PBS_3 shown in Fig. 2 or Fig. 7 to perform the same function. Further, a polarization beam splitter comprises generally a plurality of prisms and multiple layers of film composed by evaporation between the prisms, which are referred as the boundary plane in the explanations for the various embodiments, however, a glass plate on which multiple layers of film are composed by evaporation may also be used for the purpose.

From the foregoing, it can be understood that the polarization converters of the present invention uses a few number of optical components to change or produce a linearly polarized light beam efficiently.

Figs. 9 to 12 show some forms of display system using a polarization converter PCE according to the present invention. The polarization converter PCE can be any one of the polarization converters PCE_1 through PCE_5 and PCE_8 which receive a randomly polarized light from one direction and project a beam of linearly polarized light in another direction which is 90° to the one direction. If the randomly polarized incident light comes in the same direction as the linearly polarized light beam which is intended to project out of the polarization converter PCE, the polarization converter PCE_6 or PCE_7 may be utilized in the display systems shown in Figs. 9, 11, and 12.

In Fig. 9, a randomly polarized light is converted to a beam of S-polarized light and is projected toward a transmissive type liquid crystal light modulator 11 where the S-polarized light beam undergoes a polar modulation, further, the light thus modulated advances through an analyzer 12 to undergo brightness modulation, the brightness modulated light thus obtained may be projected on a screen (not shown) through a projector lens (not shown) for display.

In Fig. 10, a reflective type liquid crystal light modulator 13 is placed in place of the liquid crystal light modulator 11 in Fig. 9, as a result, a polar modulated light from the liquid crystal light modulator 13 is projected back to the polarization converter PCE which serves as an analyzer to pass only a P-polarized light component of the polar modulated light. The output P-polarized light may be projected on a screen through a projector lens (both not shown) for display.

In Fig. 11, the S-polarized light produced by the polarization converter PCE is projected to a polarization beam splitter PBS which is identical in structure to the first polarization beam splitter PBS_1 referred in Fig. 1, which, directs the S-polarized light to the reflective type liquid crystal light modulator 13 where the S-polarized light undergoes a polar modulation and is reflected back to the polarization beam splitter PBS, as a result, only a P-polarized light component is passed through the polarization beam splitter PBS, which may be projected on a screen through a projector lens (both not shown) for display.

In Fig. 12, the S-polarized light produced by the polarization converter PCE is projected toward the reflective type liquid crystal light modulator 13. The modulator 13 is aligned 45° to a path of the S-polarized light incident thereto and polar-modulates the S-polarized light, and directs it to the analyzer 12 for brightness modulation thereby, as a result, a brightness modulated linearly polarized (P-polarized) light beam is projected on a screen through a project lens (both not shown) for display.

Note that unlike in the embodiment shown in Fig. 10, the polarization converter PCE in Fig. 9, 11, and 12 does not have a role of analyzer. The liquid crystal light modulator of a type transmissive (11) or reflective (13) is typically a twisted nematic type liquid crystal, however, other types of light modulator having a polarization or a birefringence characteristic such as lithium niobate or PLZT material, may be utilized. Further, the polarization converters of the present invention may be applied to not only image display systems but to other systems such as light computers and recording/playback systems.

Claims

1. A polarization converter for producing a beam of linearly polarized light from a randomly polarized light characterized by comprising :
   first means (PBS_1, PBS_3, PBS_4) for receiving the randomly polarized light, out of which said first means projects first polarized light in a predetermined direction, and projects a second polarized light having a predetermined angular relationship with the first polarized light ;
   second means (PCD_1, PCD_2, 6, 9, M) for converting the second polarized light into a third polarized light a polarization of which is identical to that of the first polarized light, and
   third means (PBS_2, PBS_3, 7, 8) for producing said beam of linearly polarized light advancing in said predetermined direction by directing said third polarized light parallel with said first polarized light.

2. A polarization converter as claimed in claim 1, in which said first means is a polarization beam splitter (PBS_1, PBS_4) comprising a pair of prisms combined together forming a 45 degree boundary plane (PBS_{3a}) therebetween, which functions as a polarizer.

3. A polarization converter as claimed in claim 1, in which said second means is a polarization converting means (PCD_1) contacted to said third means, said polarization converting means comprising a pair of electrodes (Et, Er) interposing a photomodulation layer (PML), an electric source (VAC) to apply a bias potential between the pair of electrodes, and means (M) reflecting said second polarized light projected from said first means, one of said pair of electrodes being transparent to pass the second polarized light toward said photomodulation layer and said reflecting means.

4. A polarization converter as claimed in claim 1, in which said second means is a Fresnel rhomb prism (9) and a mirror (M) provided to one end thereof, and another end of the Fresnel rhomb prism being attached to said third means.

5. A polarization converter as claimed in claim 1, in which said second means is a quarterwave plate (5) and a mirror (M) laminated thereto.

6. A polarization converter as claimed in claim 1, in which said second means is a halfwave plate (6) interposed between said first and third means.

7. A polarization converter as claimed in claim 2, in which said polarization converter further comprises an additional polarization beam splitter (PBS_2) as said third means having an identical structure to said polarization beam splitter, said additional polarization splitter and said polarization splitter being stacked together in such a manner that respective boundary planes (PBS_{3a}, PBS_{3b}) thereof form a right angle.

8. A polarization converter as claimed in claim 1, comprises a three prism structure (PBS_3) as said first and third means in such a configuration that three prisms (1, 2, 3) are stacked to form two boundary planes having a 90 degrees angular relationship therebetween, and each of the boundary planes functions as a polarizer.

9. A polarization converter as claimed in claim 8, in which said three prism structure has a top (2), center (1) and bottom (3) prism stacked together, an upper half of the center prism receives said randomly polarized light and transmit thereof to the top prism to produce said first polarized light, and said second means (PCD_1) is attached to a lower half of the center prism and projects said third polarized light toward the bottom prism.

10. A polarization converter as claimed in claim 6, in which said third means is a prism (7) reflecting said third polarized light into said predetermined direction.

11. A polarization converter as claimed in claim 6, in which said third means is a reflective mirror (8) reflecting said third polarized light into said predetermined direction.

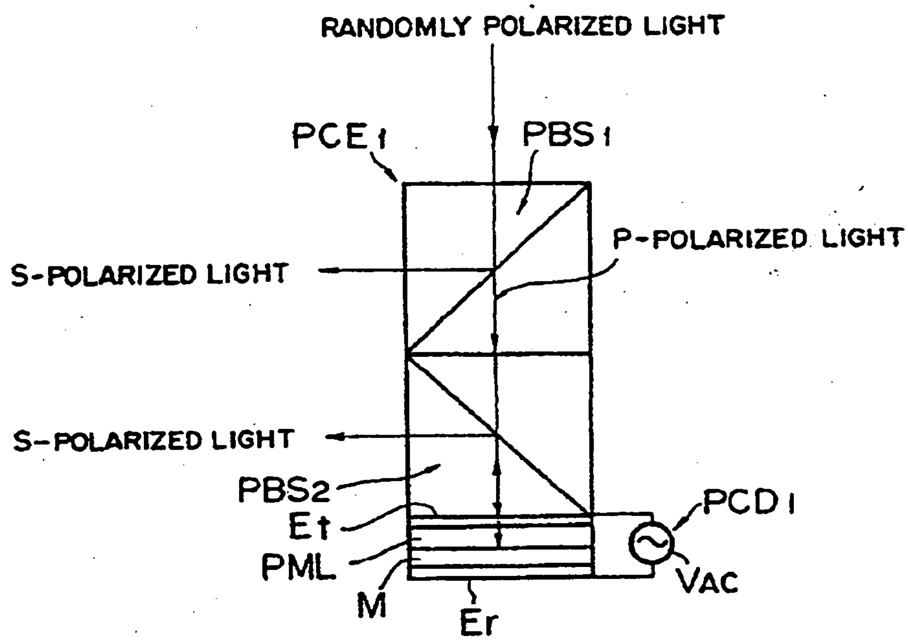

RANDOMLY POLARIZED LIGHT
PCE1
PBS1
P-POLARIZED LIGHT
S-POLARIZED LIGHT
S-POLARIZED LIGHT
PBS2
Et
PCD1
PML
VAC
M
Er

FIG. 1

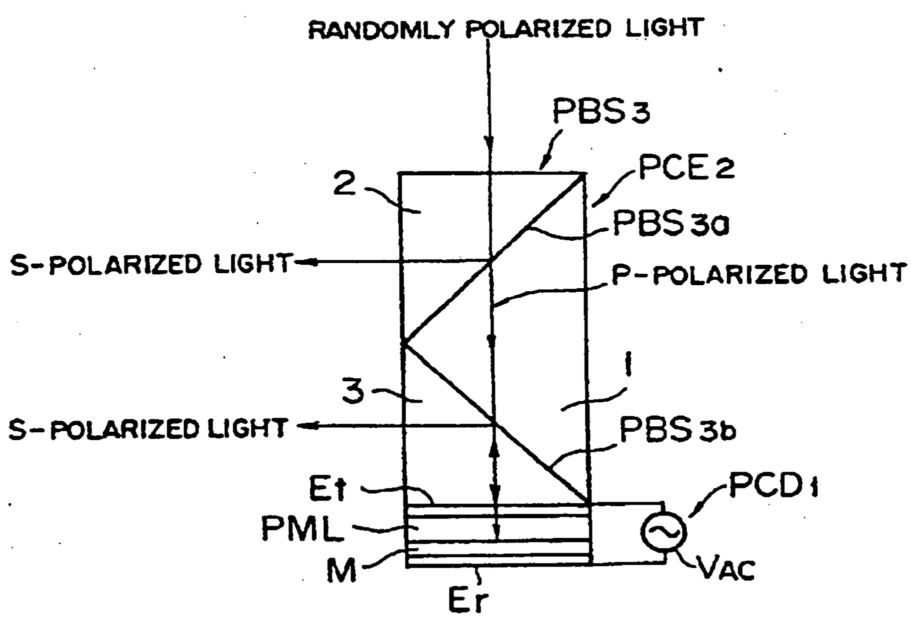

RANDOMLY POLARIZED LIGHT
PBS3
2
PCE2
PBS3a
S-POLARIZED LIGHT
P-POLARIZED LIGHT
1
3
S-POLARIZED LIGHT
PBS3b
Et
PCD1
PML
M
VAC
Er

FIG. 2

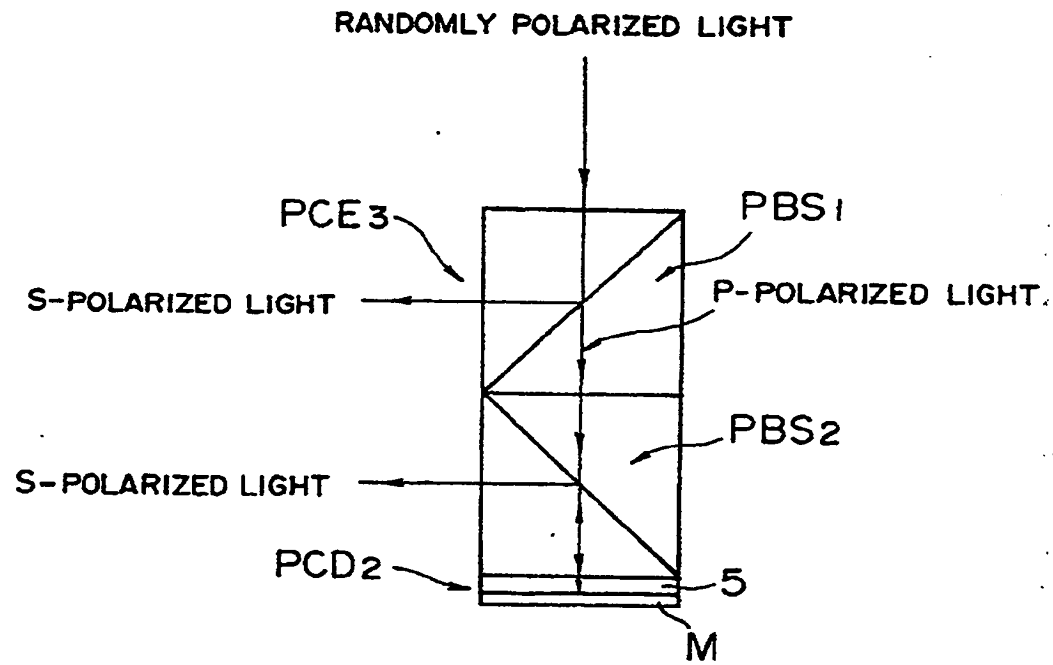

RANDOMLY POLARIZED LIGHT
PCE3
PBS1
S-POLARIZED LIGHT
P-POLARIZED LIGHT
PBS2
S-POLARIZED LIGHT
PCD2
5
M

FIG. 3

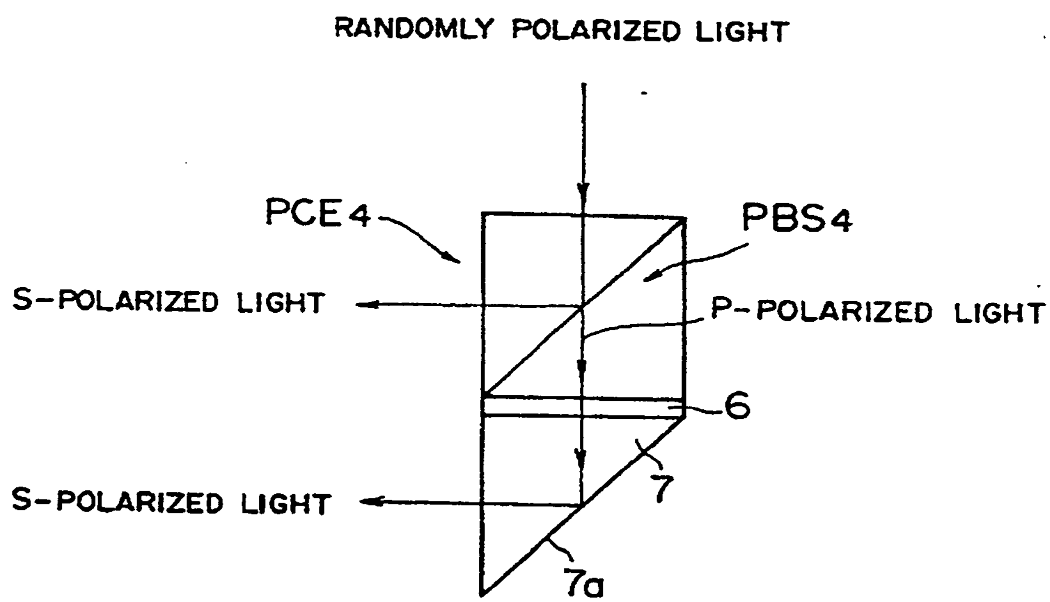

RANDOMLY POLARIZED LIGHT
PCE4
PBS4
S-POLARIZED LIGHT
P-POLARIZED LIGHT
6
7
S-POLARIZED LIGHT
7a

FIG. 4

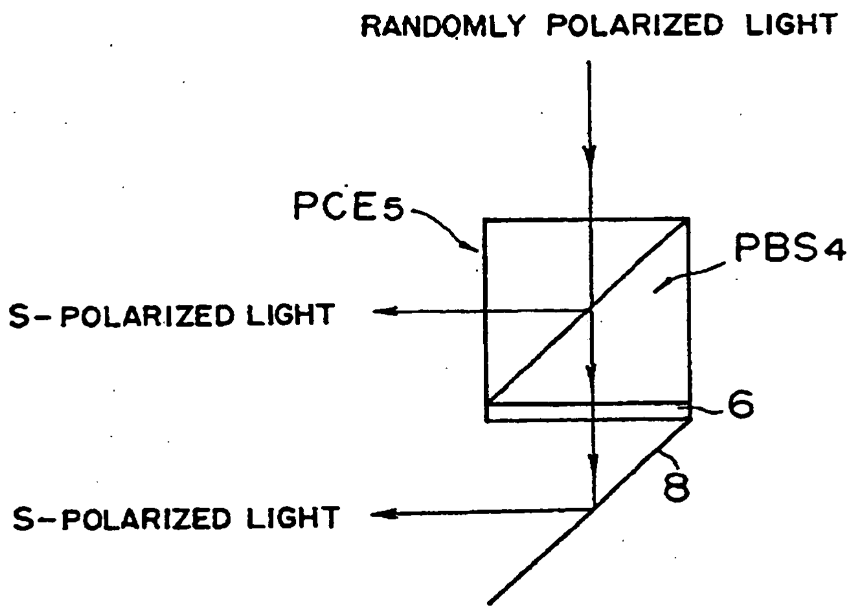
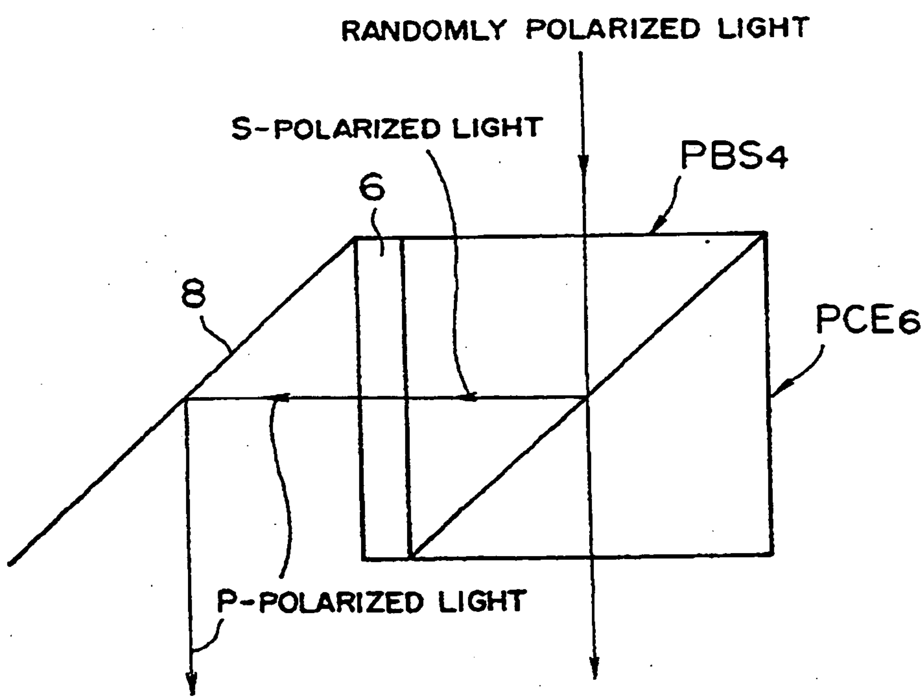

RANDOMLY POLARIZED LIGHT
PCE5
PBS4
S-POLARIZED LIGHT
6
8
S-POLARIZED LIGHT

FIG.5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S-POLARIZED LIGHT
PBS4
6
8
PCE6
P-POLARIZED LIGHT

FIG. 6

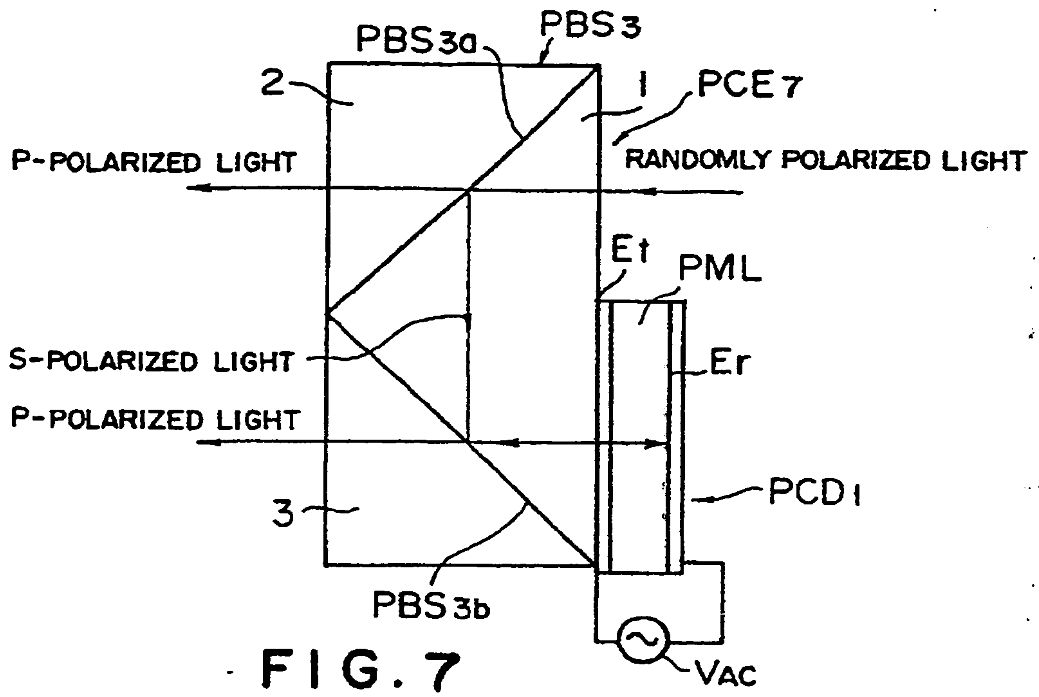
PBS3a
PBS3
2
1
PCE7
P-POLARIZED LIGHT
RANDOMLY POLARIZED LIGHT
Et
PML
S-POLARIZED LIGHT
Er
P-POLARIZED LIGHT
PCD1
3
PBS3b
VAC

FIG. 7

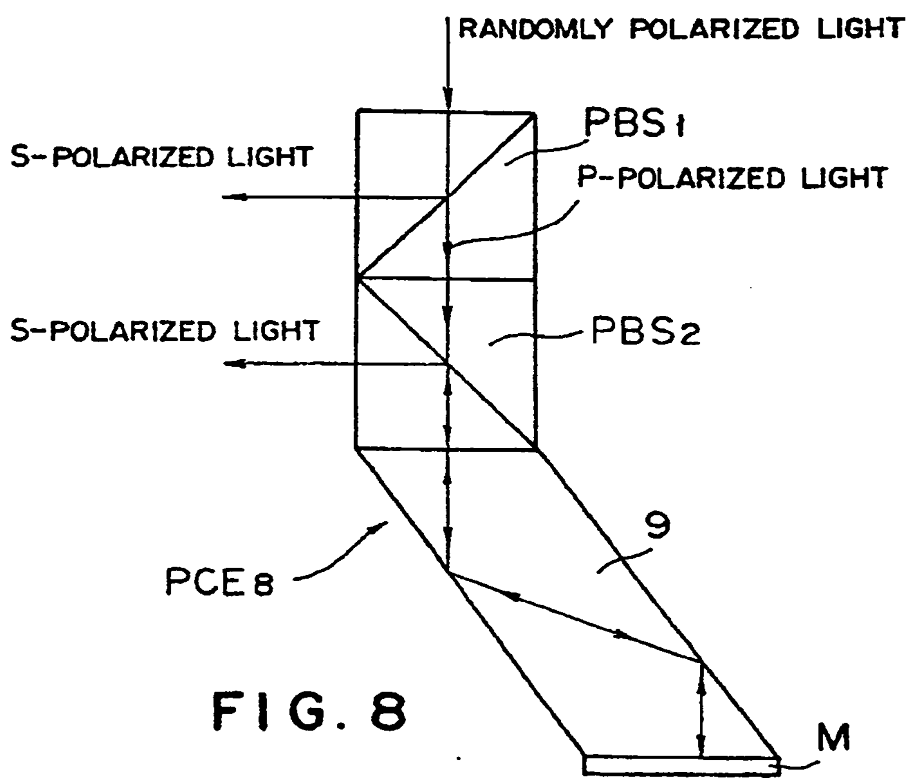
RANDOMLY POLARIZED LIGHT
PBS1
S-POLARIZED LIGHT
P-POLARIZED LIGHT
S-POLARIZED LIGHT
PBS2
9
PCE8
M

FIG. 8

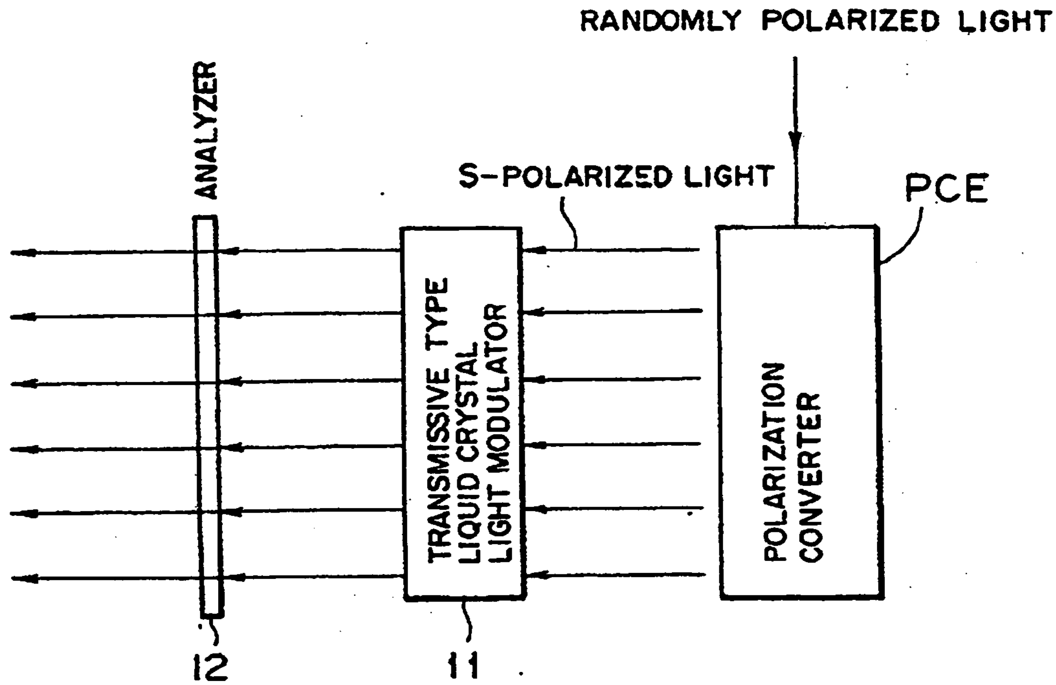
RANDOMLY POLARIZED LIGHT
ANALYZER
S-POLARIZED LIGHT
PCE
TRANSMISSIVE TYPE LIQUID CRYSTAL LIGHT MODULATOR
POLARIZATION CONVERTER
12
11

FIG. 9

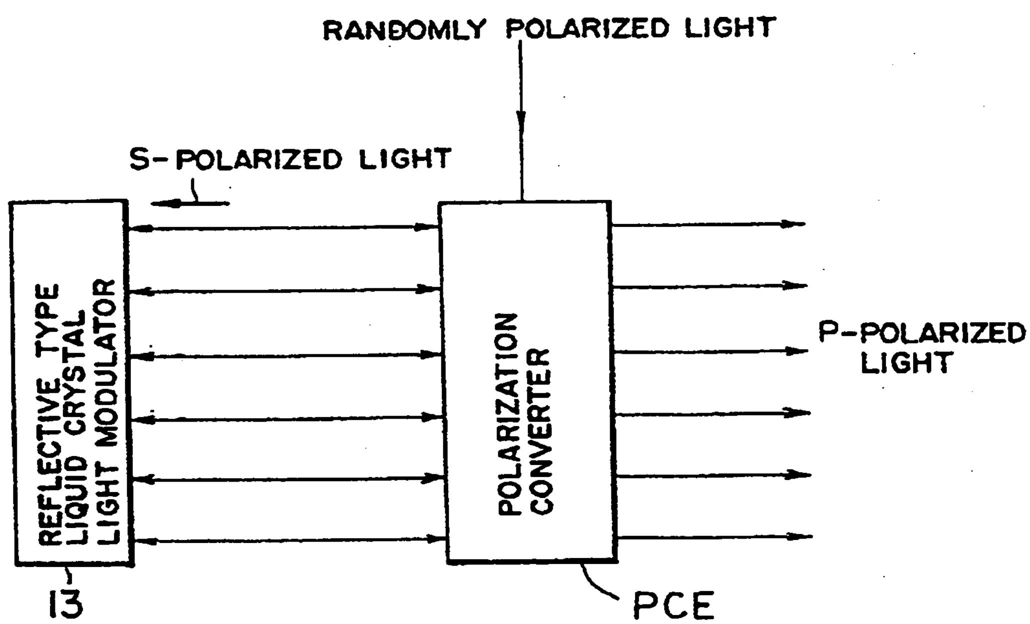
RANDOMLY POLARIZED LIGHT
S-POLARIZED LIGHT
REFLECTIVE TYPE LIQUID CRYSTAL LIGHT MODULATOR
POLARIZATION CONVERTER
P-POLARIZED LIGHT
13
PCE

FIG. 10

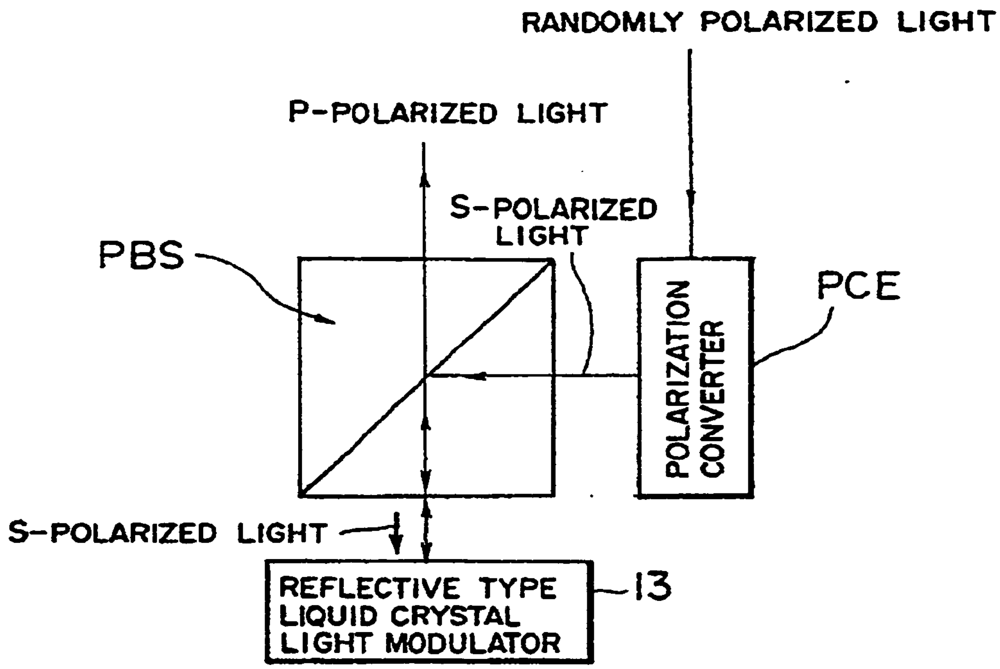
RANDOMLY POLARIZED LIGHT
P-POLARIZED LIGHT
S-POLARIZED LIGHT
PBS
POLARIZATION CONVERTER
PCE
S-POLARIZED LIGHT
REFLECTIVE TYPE LIQUID CRYSTAL LIGHT MODULATOR
13

FIG. 11

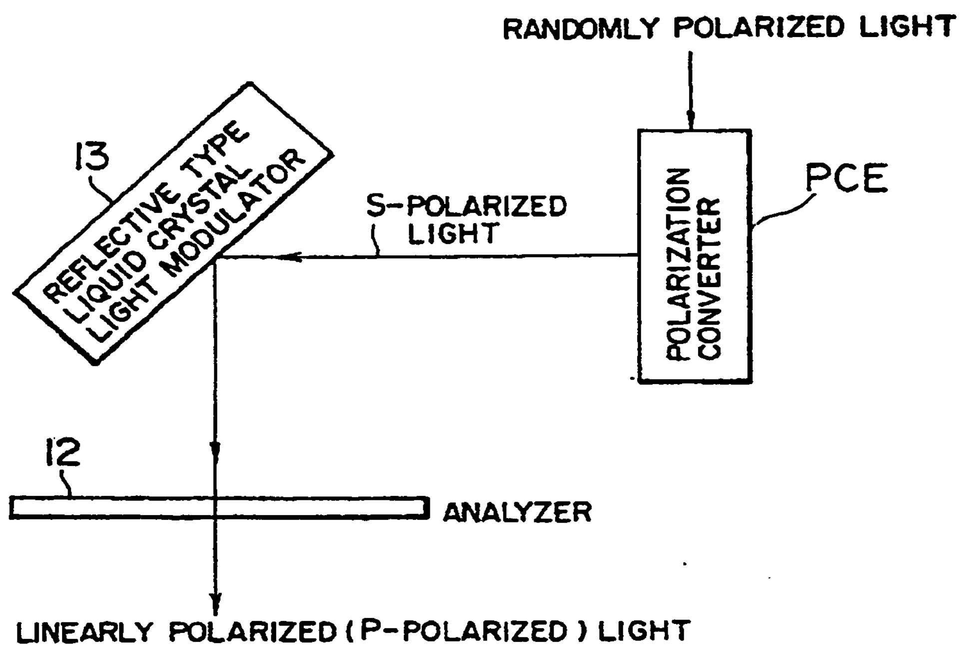
RANDOMLY POLARIZED LIGHT
13
REFLECTIVE TYPE LIQUID CRYSTAL LIGHT MODULATOR
S-POLARIZED LIGHT
POLARIZATION CONVERTER
PCE
12
ANALYZER
LINEARLY POLARIZED (P-POLARIZED) LIGHT

FIG. 12

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(71) Applicant: VICTOR COMPANY OF JAPAN, LTD.
12, Moriya-Cho 3-Chome, Kanagawa-Ku
Yokohama-Shi, Kanagawa-Ken (JP)

(72) Inventor: Takanashi, Itsuo
3-7-12 Oomachi, Kamakura-shi
Kanagawa-ken (JP)
Inventor: Nakagaki, Shintaro
6-2 Koyo-cho
Miura-shi, Kanagawa-ken (JP)
Inventor: Negishi, Ichiro
301, Copo Kotobuki, 5-8-10, Ooyabe
Yokosuka-shi, Kanagawa-ken (JP)
Inventor: Suzuki, Tetsuji
202, Morisaki Park Sanei, 2-3-13, Morisaki
Yokosuka-shi, Kanagawa-ken (JP)
Inventor: Tatsumi, Fujiko
2-12-3, Chuo, Nishi-ku
Yokosuka-shi, Kanagawa-ken (JP)
Inventor: Takahashi, Ryusaku
302, Château obi, 1719-1, Nobi
Yokosuka-shi, Kanagawa-ken (JP)
Inventor: Maeno, Keiichi
102, Morisaki Park Sanei, 2-3-13, Morisaki
Yokosuka-shi, Kanagawa-ken (JP)

(74) Representative: Crawford, Andrew Birkby et al
A.A. THORNTON & CO. Northumberland
House 303-306 High Holborn
London WC1V 7LE (GB)

(54) **Polarization converter for converting randomly polarized light to linearly polarized light.**

(57) An efficiency polarization converter of few optical components for converting a randomly polarized light into a single beam of linearly polarized light, comprises a first optical device receiving the random light and projecting two linearly polarized lights one projected in a first direction, another to a second optical device which changes the polarization plane thereof, the polarization changed light being directed by a third optical device to the first direction, thereby the two linearly polarized light are combined and aligned to have a common polarization to become the single beam linearly polarized light projected in the first direction. Typical first optical device is a polarization beam splitter (PBS_1, PBS_4), a typical second optical device is a quarterwave plate with a mirror (M), a halfwave plate (6) or a Fresnel rhomb prism (9) with a mirror (M), or a photomodulation material (PML) interposed between biased electrodes (Et, Er) with a mirror (M), a typical third optical device is a polarization beam splitter (PB_2), a prism (7) or a mirror (M). The first and third optical devices may be combined to a 3-prism structure (PB_3). The polarization converter may be used with liquid crystal light modulators (11, 13) to utilize image display systems.

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Jouve, 18, rue Saint-Denis, 75001 PARIS

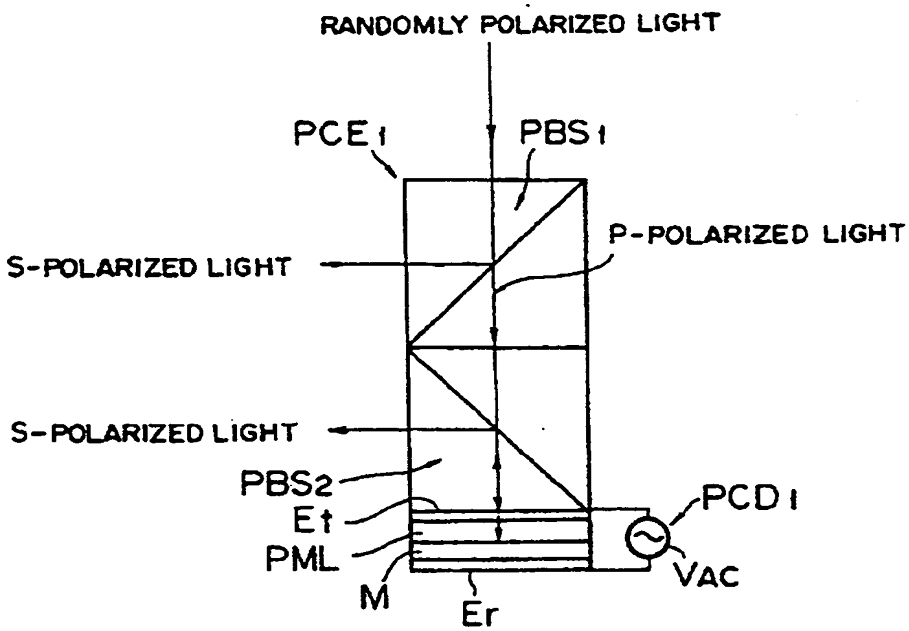
RANDOMLY POLARIZED LIGHT
PCE1
PBS1
P-POLARIZED LIGHT
S-POLARIZED LIGHT
S-POLARIZED LIGHT
PBS2
Et
PML
M
Er
PCD1
VAC

FIG. 1

European Patent Office

EUROPEAN SEARCH REPORT

Application Number

EP 90 31 3155

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (Int. Cl.5)
X	PATENT ABSTRACTS OF JAPAN vol. 12, no. 439 (P-788)18 November 1988 & JP-A-63 168 622 (CANON INC)	1,2,7	G02B27/28 G02B5/30
Y		8	
A	* abstract *	3	
X	PATENT ABSTRACTS OF JAPAN vol. 13, no. 089 (P-836)2 March 1989 & JP-A-63 271 313 (NIKON CORP) * abstract *	1,4,6, 10,11	
Y	DE-A-43 569 (A. KRUSS) * the whole document *	8	

TECHNICAL FIELDS SEARCHED (Int. Cl.5)

G02B

The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
THE HAGUE	27 DECEMBER 1991	VAN DOREMALEN J.C.

CATEGORY OF CITED DOCUMENTS

X : particularly relevant if taken alone
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